

We Claim:

1. In a Combined Industrially Reformed hydrogen and Catalytic Exchange ("CIRCE") heavy water production system having a series of cascaded stages, the first stage comprising a first stage catalytic exchange column for passing liquid water in deuterium exchange relation with hydrogen gas to produce a deuterium enriched first stage liquid water stream and an industrial steam reformer for evolving a hydrogen gas product stream, a portion of said deuterium enriched first stage liquid water stream from said first stage catalytic exchange column being applied as feed to said reformer and said reformer hydrogen gas product stream being applied as feed to said first stage catalytic exchange column, a Bithermal Hydrogen Water ("BHW") second stage comprising cold and hot second stage catalytic exchange columns for passing liquid water in deuterium exchange relation with hydrogen gas, said cold second stage catalytic exchange column operating at a lower temperature effective to cause transfer of deuterium from hydrogen gas to liquid water, said second stage hot catalytic exchange column operating at a higher temperature effective to cause transfer of deuterium from liquid water to hydrogen gas, means for circulating hydrogen gas in a stream through said second stage cold and hot catalytic exchange columns, means for applying a portion of said deuterium enriched first stage liquid water stream from said first stage catalytic exchange column to said second stage cold catalytic exchange column in countercurrent relation to said hydrogen gas stream to produce a deuterium enriched second stage liquid water stream, means for applying a portion of said second stage liquid water stream to said second stage hot catalytic exchange column in countercurrent relation to said hydrogen gas stream to produce a deuterium depleted second stage liquid water stream, means for applying said deuterium depleted second stage liquid water stream to said reformer, means for removing a portion of said deuterium enriched second stage liquid water stream produced by said second stage cold catalytic exchange column from said second stage.
2. The system of claim 1 further comprising a Bithermal Hydrogen Water ("BHW") third stage comprising third stage cold and hot catalytic exchange columns for passing liquid water in deuterium exchange relation with hydrogen gas, said third stage cold catalytic exchange column operating at a lower temperature effective to cause transfer of deuterium from hydrogen gas to liquid water, said third stage hot catalytic exchange

column operating at a higher temperature effective to cause transfer of deuterium from liquid water to hydrogen gas, means for circulating said hydrogen gas in a stream through said third stage cold and hot catalytic exchange columns, means for applying said removed portion of said deuterium enriched second stage liquid water stream to said third stage cold catalytic exchange column in countercurrent relation to said hydrogen gas stream to produce a deuterium enriched third stage liquid water stream, means for applying a portion of said third stage liquid water stream to said third stage hot catalytic exchange column in countercurrent relation to said hydrogen gas stream to produce a deuterium depleted third stage liquid water stream, means for applying said deuterium depleted third stage liquid water stream to said second stage hot catalytic exchange column, means for removing a portion of said deuterium enriched third stage liquid water stream from said third stage.

3. The system of claim 2 further comprising a Combined Electrolysis and Exchange (“CECE”) fourth stage comprising a fourth stage catalytic exchange column for passing liquid water in deuterium exchange relation with hydrogen gas to produce a deuterium enriched fourth stage liquid water stream, electrolysis cells for evolving from said deuterium enriched fourth stage liquid water stream a deuterium enriched liquid condensate stream and an electrolytic hydrogen gas stream, means for passing said electrolytic hydrogen gas stream through said fourth stage catalytic exchange column, means for applying said removed portion of said deuterium enriched third stage liquid water stream to said fourth stage catalytic exchange column in countercurrent relation to said hydrogen gas stream to produce a deuterium enriched fourth stage liquid water stream, means for applying said deuterium enriched fourth stage liquid water stream to said electrolysis cells, means for removing a portion of said deuterium enriched liquid condensate stream from said fourth stage.

4. The system of claim 1 further comprising a pre-enrichment first stage cold catalytic exchange column, wherein said portion of said deuterium enriched first stage liquid water stream from said first stage catalytic exchange column is first applied to said pre-enrichment first stage cold catalytic exchange column before being applied to said second stage cold catalytic exchange column and said reformer hydrogen gas product stream is

first applied to said pre-enrichment first stage cold catalytic exchange column in countercurrent relation to said deuterium enriched first stage liquid water stream before being applied to said first stage catalytic exchange column.

5. In a Combined Industrially Reformed hydrogen and Catalytic Exchange (“CIRCE”) heavy water production system having a series of cascaded stages, the first stage comprising a first stage catalytic exchange column for passing liquid water in deuterium exchange relation with hydrogen gas to produce a deuterium enriched first stage liquid water stream and an industrial steam reformer for evolving a hydrogen gas product stream, said deuterium enriched first stage liquid water stream from said first stage catalytic exchange column being applied as feed to said reformer and a portion of said reformer hydrogen gas product stream being applied as feed to said first stage catalytic exchange column, a Bithermal Hydrogen Water (“BHW”) second stage comprising cold and hot second stage catalytic exchange columns for passing liquid water in deuterium exchange relation with hydrogen gas, said cold second stage catalytic exchange column operating at a lower temperature effective to cause transfer of deuterium from hydrogen gas to liquid water, said second stage hot catalytic exchange column operating at a higher temperature effective to cause transfer of deuterium from liquid water to hydrogen gas, means for circulating said liquid water in a stream through said second stage cold and hot catalytic exchange columns, means for applying a portion of said reformer hydrogen gas product stream to said second stage hot catalytic exchange column in countercurrent relation to said liquid water stream to produce a deuterium enriched second stage hydrogen gas stream, means for applying said deuterium enriched second stage hydrogen gas stream to said second stage cold catalytic exchange column in countercurrent relation to said liquid water stream to produce a deuterium depleted second stage hydrogen gas stream and a deuterium enriched second stage liquid water stream, means for applying said deuterium depleted second stage hydrogen gas stream to first stage catalytic exchange column, means for removing a portion of said deuterium enriched second stage liquid water stream produced by said second stage cold catalytic exchange column from said second stage.

6. The system of claim 5 further comprising a Bithermal Hydrogen Water ("BHW") third stage comprising third stage cold and hot catalytic exchange columns for passing liquid water in deuterium exchange relation with hydrogen gas, said third stage cold catalytic exchange column operating at a lower temperature effective to cause transfer of deuterium from hydrogen gas to liquid water, said third stage hot catalytic exchange column operating at a higher temperature effective to cause transfer of deuterium from liquid water to hydrogen gas, means for circulating said hydrogen gas in a stream through said third stage cold and hot catalytic exchange columns, means for applying said removed portion of said deuterium enriched second stage liquid water stream to said third stage cold catalytic exchange column in countercurrent relation to said hydrogen gas stream to produce a deuterium enriched third stage liquid water stream, means for applying a portion of said third stage liquid water stream to said third stage hot catalytic exchange column in countercurrent relation to said hydrogen gas stream to produce a deuterium depleted third stage liquid water stream, means for applying said deuterium depleted third stage liquid water stream to said second stage hot catalytic exchange column, means for removing a portion of said deuterium enriched third stage liquid water stream from said third stage.

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7. The system of claim 6 further comprising a Combined Electrolysis and Exchange ("CECE") fourth stage comprising a fourth stage catalytic exchange column for passing liquid water in deuterium exchange relation with hydrogen gas to produce a deuterium enriched fourth stage liquid water stream, electrolysis cells for evolving from said deuterium enriched fourth stage liquid water stream a deuterium enriched liquid condensate stream and an electrolytic hydrogen gas stream, means for passing said electrolytic hydrogen gas stream through said fourth stage catalytic exchange column, means for applying said removed portion of said deuterium enriched third stage liquid water stream to said fourth stage catalytic exchange column in countercurrent relation to said hydrogen gas stream to produce a deuterium enriched fourth stage liquid water stream, means for applying said deuterium enriched fourth stage liquid water stream to said electrolysis cells, means for removing a portion of said deuterium enriched liquid condensate stream from said fourth stage.

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8. The system of claim 5 further comprising a pre-enrichment first stage hot catalytic exchange column, wherein said portion of said reformer hydrogen gas product stream is first applied to said pre-enrichment first stage hot catalytic exchange column before being applied to said second stage hot catalytic exchange column and said deuterium enriched first stage liquid water stream from said first stage catalytic exchange column is applied to said pre-enrichment first stage hot catalytic exchange column in countercurrent relation to said reformer hydrogen gas product stream before being applied as feed to said reformer.

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